TABLE OF CONTENTS

3.5 Simulation of the Lower East Coast of South Florida 185
3.5.1 Introduction 185
3.5.2 Water Supply Needs Calculations 185
3.5.3 Unsaturated Zone Accounting in the LEC 193
3.5.4 Water Shortage Plan for the LEC 195
3.5.5 Public Water Supply Well Pumpage 199

LIST OF FIGURES

Figure 3.5.2.1 Primary Structures Used in Making Water Supply Deliveries to the Three Service Areas within the Lower East Coast 186
Figure 3.5.2.2 Hypothetical Canal Network Used to Explain Water Supply Needs Calculations in the South Florida Water Management Model 187
Figure 3.5.2.3 Sequence of Water Supply Needs Calculations for the Hypothetical Canal Network 191
Figure 3.5.3.1 Systems Diagram of Processes Simulated in the South Florida Water Management Model for Irrigated Cells within the Lower East Coast Service Area 195
Figure 3.5.4.1 Location of Key Trigger Cells in the South Florida Water Management Model Used to Trigger Water Restrictions in the Lower East Coast Developed Area 198
Figure 3.5.5.1 Distribution of Annual Average Public Water Supply Pumpage (1996-2000) in the Lower East Coast Based on the South Florida Water Management Model Grid Network .. 201

LIST OF TABLES

Table 3.5.2.1 Canal Definition Data for Example Hypothetical Canal Network 188
Table 3.5.2.2 Routing Information for Example Hypothetical Canal Network 188
Table 3.5.2.3 Branch Information for Example Hypothetical Canal Network 188
Table 3.5.4.1 Proposed Cutbacks for Simulating the Short-Term Water Use Restrictions in the Lower East Coast Service Areas 196
Table 3.5.5.1 Average Daily Withdrawal (in MGD) from LEC Surficial Aquifer for Public Water Supply in Eastern Palm Beach, Broward and Miami-Dade Counties 200

3.5 SIMULATION OF THE LOWER EAST COAST OF SOUTH FLORIDA

3.5.1 Introduction

An important management option available in the model is its ability to impose short-term water restrictions on the various water users within the Lower East Coast (LEC) of South Florida. Sources for water consumption within the LEC can be broken down into three categories: (1) wellfield withdrawals made to meet public water supply needs; (2) irrigation used to satisfy supplemental requirements (in addition to rainfall) of different LEC urban water use types (landscape, nursery, agriculture, and golf course); and (3) regional deliveries made to maintain LEC canals at desired levels. These desired levels, also referred to as maintenance levels, are necessary to prevent saltwater intrusion from the eastern seaboard, and to some extent, to satisfy agricultural needs within the LEC. The first two categories use ground water from the surficial aquifer, primarily the Biscayne aquifer, while the third category utilizes surface water available from the Conservation Areas and Lake Okeechobee.

Sections 3.1 and 3.2 explain the rules involved in limiting/restricting water deliveries from the Water Conservation Areas (via "floor" elevations) to the LECSAs and from Lake Okeechobee (via supply-side management) to the LOSAs, respectively. The objective of this section is three-fold: (1) to explain how the model estimates the amount of water necessary to keep the LEC canals at their maintenance levels and how it is eventually met; (2) to show the unsaturated zone accounting procedure as it relates to the pre-processed quantities (PET, ETU, IRRIG, etc.) generated from the ET-Recharge model (refer to Section 2.3); and (3) to explain the trigger and cutback mechanisms in the model as applied to the different water use types in Lower East Coast.

3.5.2 Water Supply Needs Calculations

Lower East Coast (Figure 3.5.2.1) water supply needs on the regional surface water system (WCAs and LOK) are defined as the surface water deliveries required from outside the LEC service areas necessary to maintain the LEC canals at desired levels. LEC water supply needs can also be referred to as water use requirements or surface water requirements. Deliveries from the regional system are needed especially during dry periods when LEC groundwater levels are at their lowest and the potential for saltwater intrusion is greatest.

A canal network is a system of canals served by one or more outlets of a storage area or a reservoir. It may consist of a single canal reach or a complicated system of canal reaches. A canal reach is a continuous section of canal bounded by control structures, and can contain numerous inflow and/or outflow points. The procedure used to estimate the water supply needs will be explained by way of an example (Figure 3.5.2.2).

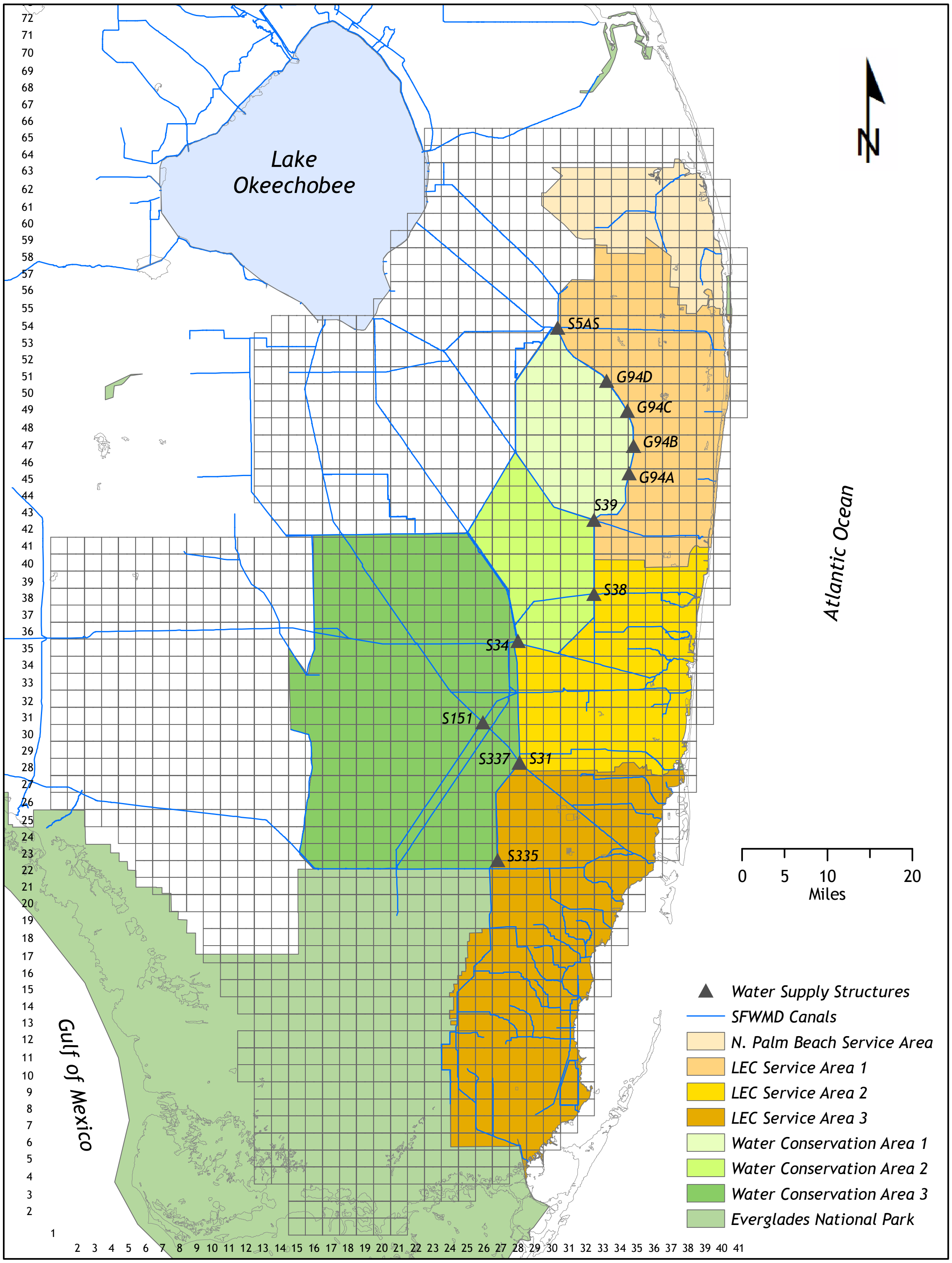

Figure 3.5.2.1 Primary Structures Used in Making Water Supply Deliveries to the Three Service Areas within the Lower East Coast

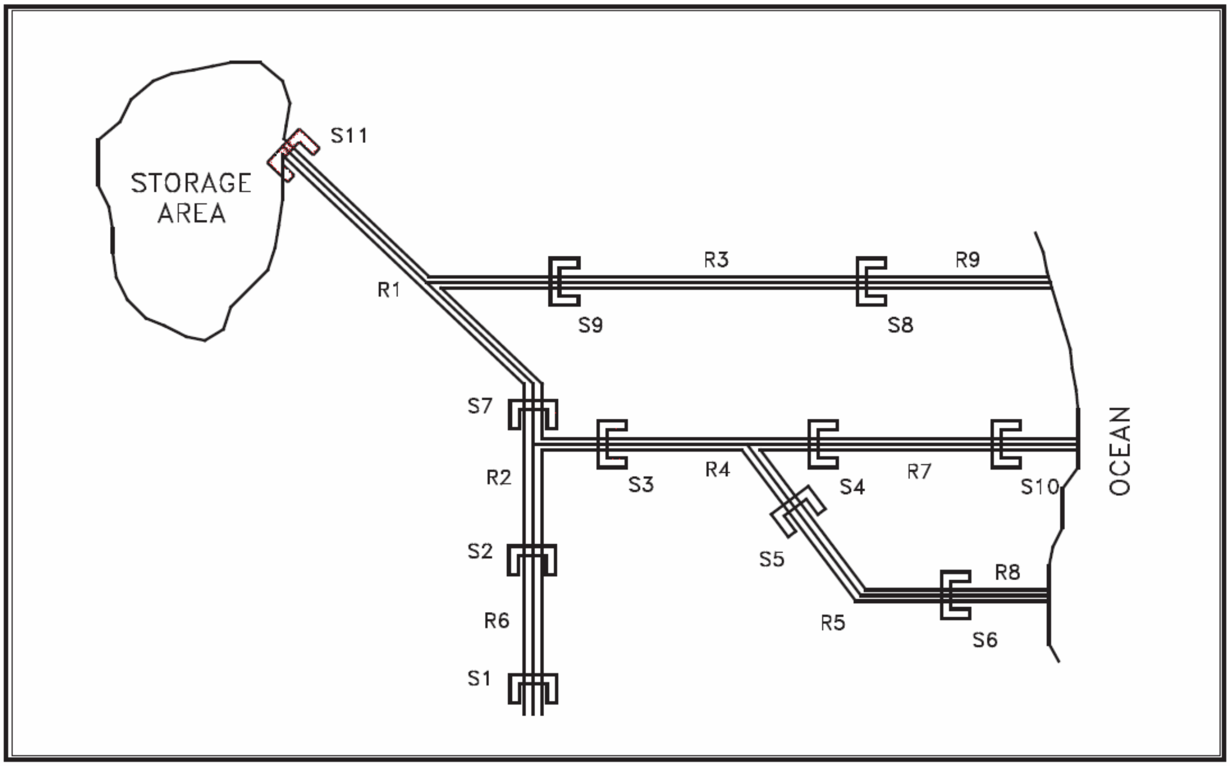

Figure 3.5.2.2 Hypothetical Canal Network Used to Explain Water Supply Needs Calculations in the South Florida Water Management Model

Hypothetical Example

For each canal reach in a canal network, the following information is needed by the model in order to estimate surface water requirements (Table 3.5.2.1):

1. Total head drop (from upstream end to downstream end) of water surface. This quantity is assumed to remain constant throughout the simulation for this example (in SFWMM v5.5, the ability to simulate some canals with varying slopes is added);
2. Canal maintenance level. A value of -9.5 means that the water level in a canal reach is not maintained;
3. Average width of the canal reach;
4. Canal-aquifer conductivity or connectivity coefficient which is used to calculate canal-groundwater seepage or in general, canal-groundwater interaction;
5. Name of upstream canal reach discharging into the canal reach of interest; and
6. Number of downstream outflows simulated for water supply, which is less than or equal to the number of outflows in canal.

To route water from a storage area through the canal system for water supply purposes, the following input information is also required for each canal reach (Table 3.5.2.2):

1. total number of outlet structures simulated in a canal reach;
2. names of downstream structures; and
3. names of canals receiving the water from each outlet structure.

Table 3.5.2.1 Canal Definition Data for Example Hypothetical Canal Network

Canal Reach Name	Head Drop (ft)	Average Width of Canal Reach (ft)	Canal-Aquifer Conductivity Coefficient (ft/day/ft-head)	Maintenance Level (ft NGVD)	Upstream Canal Reach to be Maintained	Number of Outlet Structures for Water Supply: 1 for no outlets
R1	0.3	80	3.0	5.0	none	2
R2	0.2	80	5.0	4.0	R1	2
R3	0.1	60	2.0	4.5	R1	1
R4	0.0	50	6.0	3.0	R2	2
R5	0.1	100	10.0	2.0	R4	1
R6	0.1	80	10.0	3.0	R2	1
R7	0.0	100	5.0	2.0	R4	1
R8	0.0	100	5.0	-9.5	R5	1
R9	0.0	100	3.0	-9.5	R3	1

Table 3.5.2.2 Routing Information for Example Hypothetical Canal Network

Canal Reach Name	Number of Outlet Structures	Names of Downstream Structures	Receiving Canals Corresponding to Each Outlet Structure
R1	2	S7 S9	R2 R3
R2	2	S2 S3	R6 R4
R3	1	S8	R9
R4	2	S5 S4	R5 R7
R5	1	S6	R8
R6	1	S1	free outfall
R7	1	S10	free outfall
R8	uncontrolled	none	ocean
R9	uncontrolled	none	ocean

Furthermore, the names of the farthest maintained downstream canal reach for each branch must be defined; R6, R7, R5 and R3 are used in the hypothetical example. Note that R8 and R9 are uncontrolled on the downstream end and as such, cannot be maintained. The names must be input in the order by which the model will sum the surface water requirements. With this information (Table 3.5.2.3), the model knows where to begin or continue when a canal branches into tributaries. Thus, through user-input, the model can calculate the total volume of water required to maintain any number of canal reaches within a canal network.

Table 3.5.2.3 Branch Information for Example Hypothetical Canal Network

Total Number of Branches in Canal Network	Names of Most Downstream Canal Reaches (to be maintained) for Each Branch
4	R6 R7 R5 R3

Surface Water Requirements for a Single Canal Reach

In order to estimate the surface water requirements for a single canal reach, a simple mass balance approach is used. The volume of water needed to maintain a canal reach at a desired minimum level is:

$$\mathrm{VOL}_j = \left(\mathrm{desired\_min\_level}_j - \mathrm{cstg}\right)\left(\mathrm{area}_j\right) - \sum_{i=1}^{\mathrm{ncells}_j} \mathrm{seep}_i - \sum_{i=1}^{\mathrm{ncells}_j} \mathrm{ovlnf}_i \qquad (3.5.2.1)$$

where:

j = index of the canal of interest which is the j^{th} canal input in canal definition file;
i = grid cell index where canal j passes through;
ncells_j = number of grid cells where canal reach j passes through;
cstg_j = simulated downstream stage in canal j at the beginning of time step;
area_j = surface area of canal j;
seep_i = canal-groundwater interaction; net seepage inflow into canal j; and
ovlnf_i = canal-surface water interaction at the i^{th} grid cell; net sheetflow into canal j.

The $\mathrm{desired\_min\_level}_j$ is defined for the most downstream grid cell of the canal reach, i.e., at the headwater of the downstream structure. At any other grid cell i where the canal reach passes through, the desired minimum level can be calculated as

$$\mathrm{desired\_min\_level}_{j,i} = \left[\ (\text{distance of } i^{th} \text{ grid cell from downstream structure} \div \text{total length of canal reach})(\text{total head drop})\ \right] + \mathrm{desired\_min\_level}_j \qquad (3.5.2.2)$$

$Desired\_minimum\_level_{j,i}$ and the average groundwater level at the i^{th} grid cell are used in the calculation of $seep_{j,i}$. On the other hand, $cstage_{j,i}$ and the average surface water level (land surface elevation + ponding) for the i^{th} grid cell are used in the calculation of $ovlnf_{j,i}$.

VOL_j can be positive or negative. Negative values of VOL_j represent excess water available in canal j which can be used to meet downstream needs.

The total volume of water required for water supply at any structure in a canal network [DQU(j) where j equals the canal number for the first canal directly downstream of the structure] is the sum of:

1. the volume of water required to maintain the canal reach immediately downstream of the structure (VOL_j); and
2. the total volume of water required for all canal reaches downstream of canal j.

If water is available in the canal of interest, i.e., $\mathrm{VOL}_j < 0$, and its volume is sufficient to meet downstream needs, i.e., $|\mathrm{VOL}_j| \geq \mathrm{DQU}(j-1)$, then, no water is required from the structure upstream of canal j. The total water supply requirement for the structure is then set to zero.

Surface Water Requirements for a Canal Network

The methodology applied in determining the total needs for the hypothetical canal network is summarized in Figure 3.5.2.3. The arrows and the numbers in this figure indicate the sequence of calculations. The following discussion pertains to Figure 3.5.2.3.

In order to estimate the surface water requirements for a canal network, an accumulation of needs from the most downstream canal reach to the source structure (S11 in Figure 3.5.2.2) for the network is performed. The most downstream canal reach is the last reach to receive water and the first to drop below its desired minimum level when water is insufficient. Canal reach R6 in the hypothetical canal network is the first in the series of most downstream canal reaches given in Table 3.5.2.3. Starting with this canal reach, the algorithm accumulates the water requirements while moving upstream along the main trunk (R6-R2-R1) until one of the following conditions occurs:

- **(1)** The canal of interest ($canal_j$) branches into at least one tributary whose water level(s) has(have) to be maintained. The number of tributaries equals NBRANCH(j)-1 (column 2 in Table 3.5.2.2); or
- **(2)** The trunk or main branch terminates with the canal of interest. This condition implies that variable IFF(j) equals 0 or a storage area exists upstream of the canal of interest. Variable IFF(j) is the canal reach number immediately upstream of the canal of interest. If the total needs for an entire canal network have been determined without the occurrence of condition **(1)**, the canal network either has no tributaries or none of the canal reaches in the tributaries has to be maintained.

If condition **(1)** occurs, i.e., NBRANCH(j) is greater than 1, the algorithm first determines the water requirements (VOL_j) for the canal reach of interest. In the hypothetical example, condition **(1)** first occurs for R2 which discharges into R4 (a tributary of level 1 relative to R2 which is part of the main branch) through structure S3. Then, beginning with the next most downstream canal reach being maintained (R7 as given in Table 3.5.2.3), the algorithm accumulates the needs upstream along this tributary. Initially, the number of occurrences of condition **(1)** before condition **(2)** corresponds to the number of branches beyond the main branch of the network. When condition **(2)** occurs, the algorithm will add the total needs for the tributary, i.e., DQU(iupsc) where iupsc is the canal number of the most upstream reach, to the volume of water required (VOLj) to maintain canal j immediately upstream of canal iupsc. To determine the individual total needs for each of the remaining tributaries of canal j and then continuing to the remaining canal reaches in the main branch of the canal network, the following procedure is followed:

Each time condition **(1)** occurs before the next occurrence of condition **(2)** the algorithm will accumulate the needs along the tributary in the next level, beginning with the most downstream canal reach being maintained. This will occur the same number of levels beyond the level at which condition **(2)** last occurred. Condition **(2)** occurs when the needs for all canal reaches in the tributary of interest have been determined.

The hypothetical network of canals shown in Figure 3.5.2.2 has a total of four branches or tributaries - corresponding to the number of occurrences of condition **(2)**. The general flowchart for calculating water supply needs in the model is shown in Appendix F3.

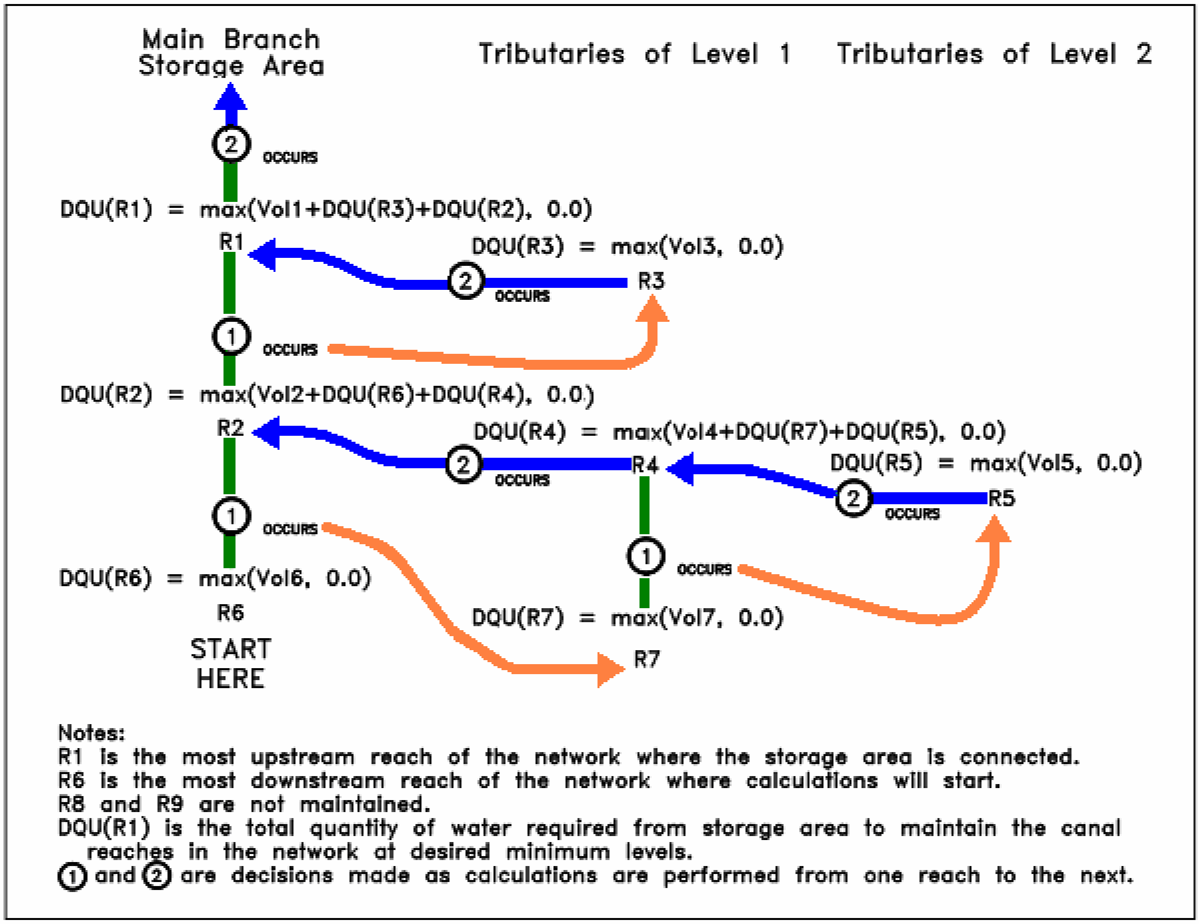

Figure 3.5.2.3 Sequence of Water Supply Needs Calculations for the Hypothetical Canal Network

The availability of surface water from a storage area such as LOK or WCA to meet downstream water requirements depends on a minimum storage level set forth for the particular storage area. Within a WCA, the canal water level below which no outflow will be made to the Lower East Coast without an equivalent amount of inflow from Lake Okeechobee is referred to as the conservation area's floor elevation.

Calculation of Available Supply. After water supply needs from a specific region, e.g., Service Area 2, are calculated, the amount of available water to meet these needs from an upstream source, e.g., WCA-2A, is calculated next. The volume of available water in a WCA is defined by the available storage within the appropriate canal reach, e.g., WCA-2A rim canal. The SFWMM calculates this volume as:

$$\text{AVVOL} = (\text{sim\_canal\_stage} - \text{min\_stage})\ (\text{sim\_surface\_area\_of\_canal})$$

$$+ \sum_{i=1}^{\text{ncells}} \text{ovlnf}_i + \sum_{i=1}^{\text{ncells}} \text{seep}_i + \sum_{i=1}^{\text{ncells}} \text{upstream inflow} \qquad (3.5.2.3)$$

where:

i	=	grid cell index where canal of interest passes through;
ncells	=	number of grid cells where canal reach of interest passes through;
sim_canal_stage	=	simulated canal stage at a given time step;
min_stage	=	floor elevation or user-defined canal stage with corresponding storage above which can be made available to meet downstream needs;
sim_surface_area_of_canal	=	length of a canal reach multiplied by its average width; (The SFWMM assumes canals with vertical walls such that this value does not vary with canal water level.)
ovlnf_i	=	canal-surface water interaction at the i th grid cell; net sheetflow into canal of interest;
seep_i	=	canal-groundwater interaction; net seepage inflow into canal of interest; and
upstream inflow	=	known net structure inflow to canal of interest.

Surface Water Deliveries from a Storage Area. In situations when a particular storage area, e.g., WCA-2A, has multiple outlet structures, e.g., S-38 and S-34, the model has to decide how to distribute the available storage among the different outlet structures. The amount of water routed through each outflow structure ($QOUT_i$) can be calculated in two ways:

1. If the user chooses the option to pro-rate the available water, i.e., "equal adversity" condition, the outflow through the i th structure will be proportional to the relative water supply demands calculated at that structure. It is calculated as:

$$ratio_i = \frac{AVVOL - \sum_{j=1}^{i-1} QOUT_j}{tot\_water\_required - \sum_{j=1}^{i-1} water\_required\ for\ j^{th}\ structure} \qquad (3.5.2.4)$$

$$Q_i = \min(ratio_i, 1.0)(\text{water required for i}^{th}\text{ structure}) \qquad (3.5.2.5)$$

$$QOUT_i = \min(Q_i, \text{structure capacity}_i) \qquad (3.5.2.6)$$

2. If the user chooses to deliver the amount of available water in the order by which the downstream structures are simulated, the outflow at the i th structure is calculated as:

$$AV_i = AVVOL - \sum_{j=1}^{i-1} QOUT_j \qquad (3.5.2.7)$$

$$Qout_i = \min(AV_i, \text{structure capacity}_i) \tag{3.5.2.8}$$

Distribution of Water Supply through the Receiving Canal Network. The ability of the system to meet water supply needs calculated above is constrained by the available storage and conveyance capacity of each structure in the receiving canal network. Therefore, conveyance limitations and water availability are checked at every structure throughout the network as water deliveries are being made.

When the supply of water becomes limited for the downstream reaches at a particular canal network, actual water delivery becomes less than the calculated water supply needs. In situations when one canal reach has two or more outflow structures delivering water and available water in the upstream canal is insufficient to meet all the requirements, then the user, similar to the way deliveries are handled from storage areas, is given the following options:

1. pro-rate available water; or
2. deliver available water to meet the requirements at the outflow structures in the order by which they are specified by the user, i.e., in the same order by which the outflow structures are input.

3.5.3 Unsaturated Zone Accounting in the LEC

As mentioned in Section 2.5, the unsaturated zone is treated as a separate control volume where infiltration, percolation, evapotranspiration and changes in soil moisture content are accounted for. Due to the level of detail required to model crop evapotranspiration rates and irrigation requirements for the major irrigation use types in the LEC (landscape, nursery, golf course and agriculture) an off-line determination, pre-processing, is performed using the ET-Recharge model (Giddings and Restrepo, 1995) whenever necessary. This section explains the accounting procedure used in the SFWMM to integrate pre-processed, cell-based, time-series data such as PET, unsaturated zone ET and irrigation schedule, with the other hydrologic components such as infiltration, percolation and runoff.

First, some assumptions used in the model with regards to unsaturated zone accounting are given. To keep the unsaturated zone water budget simple, the model assumes that all soil moisture in the unsaturated zone is readily available for plant use on any given day. This implies that the model does not differentiate between the upper and lower root zones where degrees of moisture extraction vary. The SFWMM performs a moisture accounting on the unsaturated zone whose control surface changes with time. The zone may or may not exist at all at the end of a time step depending on the location of the water table and/or the magnitude of the pre-calculated (by the ET-Recharge model) evapotranspiration amount which the model has to "remove" from the unsaturated zone. In contrast, the AFSIRS component of the ET-Recharge model performs a root zone water budget with time-invariant control volume. The SFWMM also assumes that the inefficient component of irrigation that evaporates does not significantly alter the water budget for the saturated zone.

Finally, the portion of the "inefficient" irrigation that returns to the aquifer does so in the same day it is applied such that it does not affect the solution of the groundwater flow equations. The groundwater flow equations are solved once at the end of the day and processes that can deplete as well as recharge the aquifer within the same time step may add complication to the overall algorithm of the model. Thus, the model accounts only for the net irrigation of the day and includes its contribution to the recharge term prior to the solution of the groundwater flow equations.

Figure 3.5.3.1 is a schematic of the three control volumes (ponding, unsaturated zone, saturated zone) considered in irrigated model grid cells which apply to portions of Palm Beach, Broward and Dade counties east of the WCA protective levees (Neidrauer, 1993). It is a simplified form of Figure 2.5.5.2 and shows hydrologic components pertinent to the current discussion. The movement of water among these three control volumes is accounted for in the model on a daily basis. The model distinguishes between evapotranspiration coming from the three distinct control volumes: evaporation from ponding (ETP), evapotranspiration from the unsaturated zone (ETU), and evapotranspiration from the saturated zone (ETS). It further distinguishes between unsaturated zone ET from irrigated portions of a grid cell (ETIU) and non-irrigated portions of the same cell (ETNU). Although both are pre-processed values from the ET-Recharge model, the distinction is necessary in order to implement a water restriction rule. In particular, the model assumes that only the evapotranspiration from the irrigated portions of the model will diminish as a consequence of a water restriction cutback. Net irrigation supply (NIRRSUP) refers to the portion of the pre-processed irrigation requirement that ends up in the unsaturated zone. This quantity becomes less than what is required for the day when a cutback is imposed by the "trigger" module in the model. It varies with irrigation use types. Six predominant irrigation use types were identified in the Water Shortage Plan (SFWMD,1991): urban landscape, nursery, golf course, low-volume agriculture, overhead agriculture, other agricultural usage. Given acreage information, the ET-Recharge model generates a schedule of irrigation depths per use type per SFWMM grid cell per day. This information is input to the model. The model, in turn, produces restricted (after water restrictions, if any, are implemented) unsaturated zone evapotranspiration for irrigated cells and actual (after water irrigation cutback, if any, are imposed) irrigation supply.

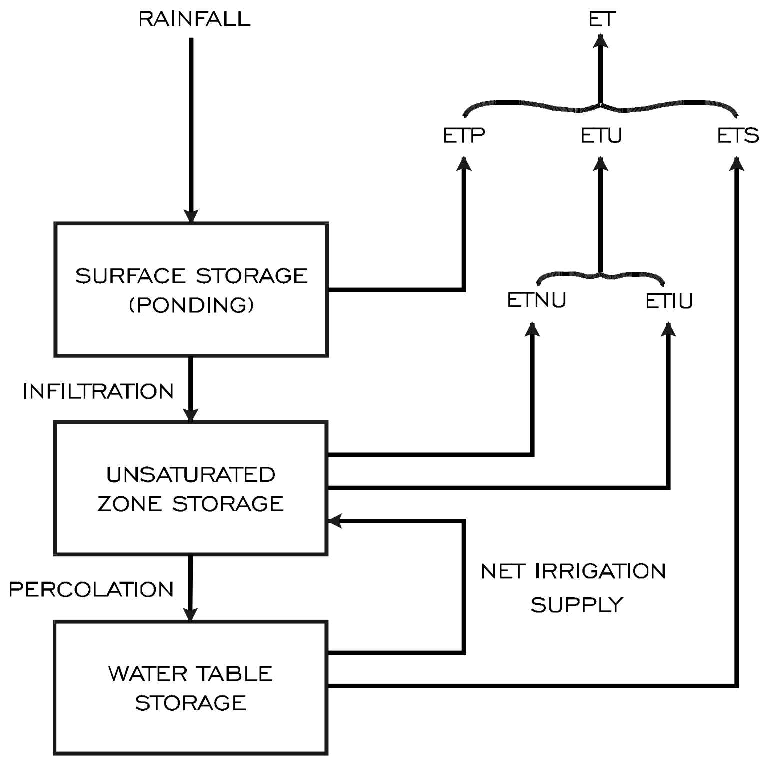

Figure 3.5.3.1 Systems Diagram of Processes Simulated in the South Florida Water Management Model for Irrigated Cells within the Lower East Coast Service Area

3.5.4 Water Shortage Plan for the LEC

The Water Shortage Plan (SFWMD, 1991) for the Lower East Coast Service Areas is the counterpart of the Supply-Side Management Plan for the Lake Okeechobee Service Area. It is the basis for incorporating a short-term water restriction scheme on the six irrigation use types and public water supply (domestic and industrial consumption). The initial process for declaring water use restriction in the field would be an evaluation of salinity levels at key monitoring points within the area. During droughts, if such levels become abnormally high, a water restriction may be "declared" after consultation among water managers within the District. However, since water quality modeling is not part of the SFWMM, a surrogate measure of water shortage is used: groundwater levels. These levels or heads are monitored within the model at key trigger wells and canals. A "trigger module" was created to incorporate provisions in the Water Shortage Plan in the South Florida Water Management Model. This module is comprised of three major tasks: (1) monitor heads at key gage locations; (2) declare water restriction phase if the monitored heads fall below some threshold values; and (3) cutback water use at appropriate locations: pumpage for public water supply consumption and irrigation, at levels consistent with the restriction phase (Table 3.5.4.1).

Table 3.5.4.1 Proposed Cutbacks for Simulating the Short-Term Water Use Restrictions in the Lower East Coast Service Areas

Water Usage or Class	Phase I	Phase II	Phase III	Phase IV
Public Water Supply*	.15	.30	.45	.60
Urban Landscape#	20.0	13.3	6.7	3.3
Nursery#	14.5	7.3	4.2	3.0
Agriculture - Overhead#	6.1	6.1	3.6	3.6
Agriculture - Low Volume#	20.0	20.0	20.0	20.0
Agriculture - Other#	20.0	20.0	4.5	3.6
Golf Course#	4.8	3.2	1.4	0.6

NOTE:*For public water supply, cutbacks are expressed in terms of fraction of the total pumpage.
#For irrigation use, cutbacks represent maximum irrigation application rates in inches per month.

First, heads at user-specified grid cells or canals are compared with prescribed limits on a daily basis. If the heads fall below one of the four limits corresponding to the four levels of drought intensity, a counter is updated of such occurrence. This step will inform the model which areas within the model domain are in a drought situation on any given day. These affected areas or "zones" are assumed to be well represented by a proper selection of trigger cells or canals where heads are being monitored. In the current implementation of the trigger module, four zones: North Service Area (with five trigger cells), Service Area 1 (with nine trigger cells), Service Area 2 (with seven trigger cells), and Service Area 3 (with eight trigger cells), are defined (Figure 3.5.4.1). The second task is carried out at the end of each month. A water restriction is declared if the frequency of heads falling below the limits reaches a user-specified maximum number of times. The appropriate water restriction phase, corresponding to the drought intensity is also identified in this task. Finally, based on user-specified levels of cutback, the amount of pumpage for affected public water supply wells is reduced and irrigation application maxima or caps per irrigation use type are imposed for the succeeding months until the end of the dry season. The amount of cutback is lowered from a more severe water restriction phase to a less severe phase within the dry season if heads at the trigger locations assigned to the zones where water usage (public water supply or irrigation use) is being cutback rebound in succeeding month(s) prior to the end of the dry season. A flowchart of the Water Shortage Plan as implemented in the SFWMM is provided in Appendix F4.

Reduced irrigation translates into a decrease in evapotranspiration. Unsaturated zone evapotranspiration rates are calculated on a daily basis by AFSIRS (Smajstrla, 1990) via the ET-Recharge model. They assume unrestricted conditions, i.e., moisture via excess rainfall and irrigation is always available. Restricted unsaturated zone evapotranspiration, on the other hand, is estimated within the SFWMM by means of a regression equation that approximates AFSIRS (refer to Section 3.3.2). The regression equation is of exponential type that treats ET from the unsaturated zone as a function of irrigation, rainfall and potential evapotranspiration.

$$ETIU_{est} = (a)(net\_irrig^{b})(mon\_rf^{c})(mon\_pet^{d}) \qquad (3.5.4.1)$$

where:

net_irrig = net monthly irrigation calculated by AFSIRS which, in turn, is called within the ET-Recharge model, (in);

mon_rf = total monthly rainfall, (in);

mon_pet = total monthly potential evapotranspiration, (in); and

a, b, c, d = regression coefficients which vary as a function of irrigation use type.

Since water use restrictions are imposed on a monthly basis, reductions in ET in months when water use restrictions are imposed can be calculated by subtracting $ETIU_{est}$ from the monthly accumulated unrestricted unsaturated zone ET, $ETIU_{AFSIRS}$. By post-processing this information the actual crop yield reduction can be related to ET reduction using a yield response function (FAO, 1988). The trigger module was designed as a simple procedure for implementing the District's Water Shortage Plan into the South Florida Water Management Model.

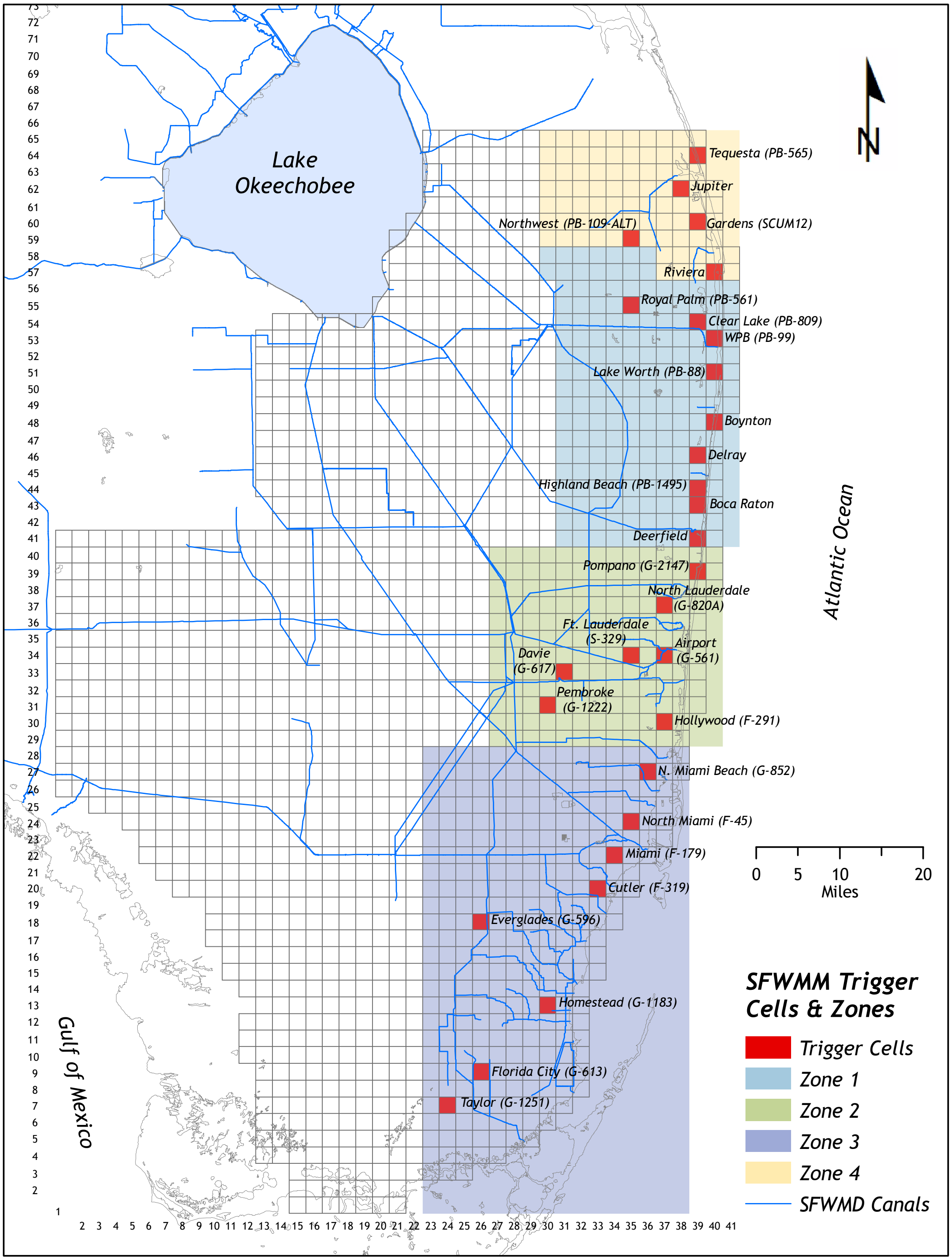

Figure 3.5.4.1 Location of Key Trigger Cells in the South Florida Water Management Model Used to Trigger Water Restrictions in the Lower East Coast Developed Area

3.5.5 Public Water Supply Well Pumpage

To update the well pumpage data for the SFWMM v5.5, a five-year update of existing data was conducted. Historical pumpage data prior to 1996 was available for earlier model versions (Brion, 1999). The primary source of data was from the USGS Water Resource Division that included several years (1996-2000) of historical water use data for fifteen South Florida counties. The data represents reported monthly pumpages from the different water utilities. Groundwater sources were also used in the final determination of pumpage input data for the model. Utility-reported pumpage for the last year of simulation, 2000, was obtained from the SFWMD Water Use Department. Raw total monthly pumpages were used in the final determination of pumpage input data for the model.

Some permits were excluded during certain years due to several reasons:

1. The permit might have already expired.
2. The permit was considered significantly small relative to the 2mile-by-2mile resolution of the model.
3. The permit referred to surface water withdrawals. Likewise, some permits were combined with others as a result of permit re-applications sometime during the 1996-2000 period of record.

A FORTRAN program was used to transform pumpages expressed in terms of permit numbers to pumpages assigned to SFWMM grid cells. The program has two basic inputs: wellfield pumpage file which shows monthly pumpages sorted by permit number and well distribution file which specifies the SFWMM grid cell assignment for each well that comprises each public water supply permit.

Five wellfield pumpage files were set up corresponding to each of the calendar years 1996 through 2000. Each file contains permit numbers, total pumpage for the year, and 12 monthly distribution factors. The wellfield pumpage files are essentially translations of the raw pumpage data obtained from the public utilities after some initial data screening/refinements as discussed above.

The information provided by a unique combination of a wellfield pumpage file and the well distribution file into the FORTRAN program produces an output file that contains monthly pumpage values assigned to appropriate model grid cells for a particular calendar year. The program was run five times, once for each of the calendar years 1996 through 2000, and the corresponding five output files were concatenated to produce a composite 1996-2000 SFWMM public water supply pumpage input file.

The pumpage data processed for this effort extended the historical data set for SFWMM. A list of the total pumpages for all LEC service areas for the modeling period of record is given in Table 3.5.5.1.

Table 3.5.5.1 Average Daily Withdrawal (in MGD) from LEC Surficial Aquifer for Public Water Supply in Eastern Palm Beach, Broward and Miami-Dade Counties

Year	Pumpage	Year	Pumpage	Year	Pumpage
1979	607	1987	735	1995	782
1980	607	1988	751	1996	810
1981	624	1989	774	1997	799
1982	614	1990	676	1998	832
1983	604	1991	728	1999	841
1984	639	1992	770	2000	874
1985	674	1993	782		
1986	686	1994	780		

In general, there is a steady increase in public water supply pumpage through the years of calibration/verification (period-of-record 1979-2000). The occasional down trends occur immediately after the dry years, e.g. 1981 and 1989. The 1979-1995 average is 696 MGD while the 1996-2000 average is 831 MGD. On an annual average basis, the distributions of pumpage for all service areas for the 1996-2000 period are shown in Figure 3.5.5.1. More information on the determination of Public Water Supply Well Pumpage Data can be found in Appendix O.

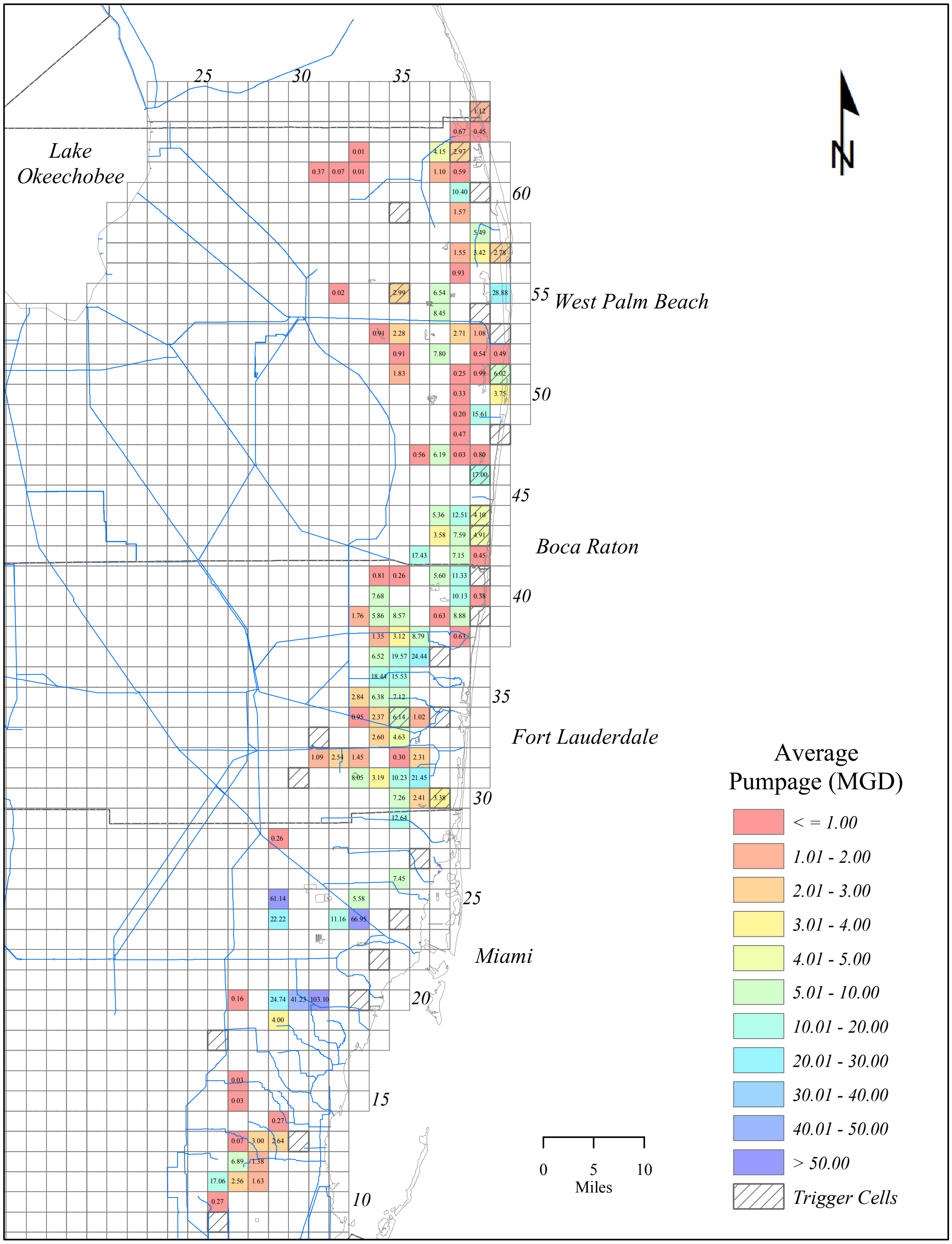

Figure 3.5.5.1 Distribution of Annual Average Public Water Supply Pumpage (1996-2000) in the Lower East Coast Based on the South Florida Water Management Model Grid Network